EXECUTIVE SUMMARY

Introduction

This document presents the baseline ecological risk assessment (BERA) for aquatic and aquatic-dependent species exposed to hazardous substances associated with industrial and other activities within the in-water Willamette River portion of the Portland Harbor Superfund site. The Portland Harbor site Study Area is defined as the reach of the Willamette River between river mile 1.9 (as measured upstream from the confluence of the Willamette and Columbia Rivers) and river mile 11.8, as well as the adjoining upland areas, although data collection for the BERA extends from RM 0.8 to RM 26.4. For the purposes of this BERA, the Willamette River is defined as all areas lower in water surface elevation than the ordinary high water mark (OHWM), including nearshore riparian zone areas not normally inundated by water. Ecological risks to terrestrial and upland species present in locations higher in elevation than the OHWM are evaluated separately as part of the investigations of individual upland source areas under the oversight of the Oregon Department of Environmental Quality (ODEQ), and are not evaluated as part of this BERA.

Purpose of the Baseline Ecological Risk Assessment

This BERA evaluates potential threats to the environment in the absence of any remedial activities. As such, it can be considered as describing ecological risks under the no action alternative of the feasibility study (FS). EPA risk managers will use the results of the BERA, along with other relevant information, to make decisions regarding remedial cleanup activities that may be needed to protect the environment. Natural resource trustees might also use the information in the BERA during their natural resource damage assessment activities.

The specific overall objectives of the BERA are twofold:

1. Identify the risks posed by chemical contaminants to aquatic and aquatic-dependent ecological receptors in, dependent upon, or associated with the Willamette River at Portland Harbor, Oregon.
2. In the event that unacceptable ecological risks are found requiring remedial actions at Portland Harbor, provide information that risk managers can use to set cleanup levels protective of ecological receptors.

Site Description – Physical Characteristics and Site History

The Willamette River originates within Oregon in the Cascade Mountain Range and flows approximately 187 miles north to its confluence with the Columbia River. The Willamette River is the 12th largest river in the contiguous United States in terms of volume of water discharged, with a flow averaging 33,800 cubic feet per second. Flows vary considerably by season, with the lowest flows occurring during the late-summer dry season, typically increasing by 10 times through the winter rainy season.

The Lower Reach of the Willamette River from River Mile (RM) 0 to approximately RM 26.5 is a wide, shallow, slow moving segment with water elevations tidally influenced by as much as three feet and with tidal reversals occurring during low flow periods as far upstream as RM 15. The river segment between RM 3 and RM 10 is the primary depositional area of the Willamette River system. The Lower Reach has been extensively dredged to maintain a 40-foot deep navigation channel from RM 0 to RM 11.6. This segment of the Lower Reach contains a highly industrialized area known as Portland Harbor, which contains a multitude of facilities and both private and municipal outfalls.

Portland Harbor is located along an 11.6-mile dredged reach of the Lower Willamette River (LWR) in Portland, Oregon (BERA Map 2-1). For over 120 years, the Portland Harbor site has been an increasingly urbanized and industrialized reach of the Willamette River. What was once a shallow, meandering river has been, since the late 1800's, redirected, filled or dredged. Today a federally maintained navigation channel extends nearly bank-to-bank in some areas. Little, if any, original shoreline or river bottom exists that has not been modified by the above actions, or as a result of them. Much of the riverbank contains overwater piers and berths, port terminals and slips, and other engineered features. Shoreline armoring such as rip rap makes up approximately half of the harbor shoreline. Some riverbank areas and adjacent parcels have been abandoned and allowed to revegetate, and beaches have formed along some modified shorelines due to relatively natural processes. A large portion of the upland area adjacent to the Study Area is zoned industrial.

Current uses of the land and water in Portland Harbor include:

- Industrial and commercial operations
- Marine activities
- Surface transportation (railroads and roadways)
- Residential
- Recreational use (including parks, boating and fishing)
- Cultural activities
- Agriculture

Human activities contributed to chemical contamination of the Study Area via multiple pathways such as direct discharges, overwater releases and spills, stormwater and wastewater outfalls, overland flow, bank erosion and groundwater. Historical and current activities responsible for the existing contamination include, but are not limited to: 1) ship building, repair and dismantling; 2) wood treatment and lumber milling; 3) storage of bulk fuels and manufactured gas production; 4) chemical manufacturing and storage; 5) municipal combined sewer overflows

(CSOs); and 6) stormwater from industrial, commercial, transportation, residential, and agricultural land uses. Various chemicals, including but not limited to metals, polychlorinated biphenyls (PCBs), dioxins/furans, pesticides, polycyclic aromatic hydrocarbons (PAHs) from petroleum and other sources, and phthalates have been released to the river over many decades.

Historical contamination in the Willamette River led EPA to perform a preliminary assessment and site investigation in 1997. Results from this investigation led to the listing of the Portland Harbor Superfund site on the National Priorities List in December 2000. In 2001, ten parties, who collectively became known as the Lower Willamette Group (LWG)[1] signed an Administrative Order on Consent with EPA in which they agreed to perform the remedial investigation (RI), of which this BERA is a part (Appendix G) of the RI report, and informs the feasibility study (FS) at the Portland Harbor site. The LWG is a subset of the approximately 150 potentially responsible parties identified by EPA at the Portland Harbor site.

Given the large number and wide variety of historical and present day contaminant sources, the multitude of different chemicals and hazardous substances released, the differences in the composition, volume and mass of hazardous substances released from the various sources, and the multiple locations within and outside of the Study Area from which contaminants have been released, it is not surprising that while some contaminants have elevated concentrations throughout much if not all of the site, many more contaminants are not distributed sitewide. Instead, many contaminants have elevated concentrations at only one or a few locations throughout the Study Area. This pattern of hazardous substance release, distribution and variable concentrations throughout the Study Area is reflected in the number of chemicals posing potentially unacceptable risks[2] in any specific section of the Study Area, as well as the areal extent and magnitude of ecological risks by exposure to each hazardous substance.

Site Description – Biological

The numerous aquatic and aquatic-dependent organisms that use the Willamette River can be divided into the following general groups: invertebrates, fishes, birds, mammals, amphibians, reptiles, and aquatic plants. All organisms present within the site make an important contribution to the ecological function of the river based on its trophic level; abundance; and

[1] The 10 organizations within the LWG that signed the 2001 Administrative Order on Consent with EPA are Arkema, Inc.; Chevron USA, Inc.; Gunderson LLC; NW Natural; City of Portland; Port of Portland; TOC Holdings Co.; ConocoPhillips Co.; Union Pacific Railroad Co.; and Evraz Oregon Steel. .

[2] The phrase 'potentially unacceptable risk' is used throughout this BERA synonymously with the more commonly used phrase 'contaminant of concern' or 'COC' to describe the contaminants that cannot be eliminated from the BERA because they pose unacceptable levels of ecological risk. Within various EPA guidance documents, the phrase chemical of concern or contaminant of concern has at least 6 different definitions, making it a somewhat imprecise term. The use of potentially unacceptable risk to describe the contaminants forwarded from the BERA into the feasibility study is also consistent with EPA risk management procedures, where it is the responsibility of the EPA risk manager, not the risk assessor to ultimately define the contaminants posing unacceptable ecological risks and which become the basis for remedial actions.

interaction with the physical, chemical, and biological environment. Riverine invertebrates are predominantly benthic (i.e. living in or associated with river bottom substrates), utilizing substrates such as fine-grained sediments, gravel and cobble, plant roots, and large woody debris. The benthic invertebrate community within the LWR is dominated by small organisms that live on or in the sediment, many of which are feeding on and processing organic material imported from upstream areas.

The Willamette River is an important migration corridor for anadromous fishes, including Pacific lamprey and multiple salmon species, and provides habitat for numerous resident fish species. Approximately 50 fish species are known to inhabit the Willamette River. Fish present in the river can be grouped into four major feeding guilds: omnivores/herbivores, benthopelagic/benthic invertivores, piscivores, and detritivores. Numerous aquatic-dependent bird species (more than 20 species commonly occur based on available information) use habitats and feed on aquatic species within the site. The trophic representation of these birds is broad and includes herbivores, carnivores and omnivores, sediment-probing invertivores and omnivores, and piscivores. Six aquatic or semi-aquatic mammals use or may use the river within the site, including opportunistic piscivores such as mink.

Section 2 of the BERA provides extensive details about biological conditions at the site, including lists of the species sampled or known to be present. Section 2 also provides additional information on physical conditions at the site.

Ecological Risk Assessment Procedure

Procedures used in this BERA to evaluate the nature, severity, and areal extent of risks to ecological receptors in Portland Harbor were based on the guidance provided in the 8-step, iterative approach to ecological risk assessment described in the EPA (1997) *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final*. The 8 steps identified in this guidance are as follows:

Screening Level Ecological Risk Assessment (SLERA)

1. Screening Level Problem Formulation and Ecological Effects Evaluation
2. Screening Level Preliminary Exposure Estimate and Risk Calculation

Baseline Ecological Risk Assessment (BERA)

3. Baseline Risk Assessment Problem Formulation
4. Study Design and Data Quality Objectives
5. Field Verification of Sampling Design

6. Site Investigation and Analysis of Exposure and Effects
7. Risk Characterization

Risk Management

8. Risk Management

No guidance document, no matter how detailed, can describe the procedures needed to fully evaluate ecological risks in a site as complex as Portland Harbor. In order to accommodate the needs of this BERA, numerous Portland Harbor site specific ecological risk assessment procedures, methodologies, memoranda and intermediate data reports and analyses have been developed and presented in a number of documents prepared by the LWG in collaboration with and with the oversight of EPA and its federal, state and Tribal partners. Among these documents are the *Portland Harbor Remedial Investigation/Feasibility Study (RI/FS) Programmatic Work Plan* (Integral et al. 2004b), the draft *Portland Harbor RI/FS, Ecological Preliminary Risk Evaluation* (Windward 2005a), and the *Problem Formulation for the Baseline Ecological Risk Assessment at the Portland Harbor Site* (EPA 2008j, included in this BERA as Attachment 2).

Chemical Contaminant and Toxicity Data Available for Ecological Risk Assessment Use

The BERA data set is a subset of the complete RI data set, including only those samples relevant to ecological exposure pathways. It does not contain sediment data from a depth greater than 30.5 cm (12 inches) below the surface water – sediment interface, nor does it include transition zone water (TZW, i.e. sediment porewater associated with the upper layer of the sediment column; consisting of groundwater, surface water, or a combination of both depending on where within the site samples were collected) collected more than 38 cm (15 inches) below the sediment – water interface. The exclusion of deeper sediment and TZW samples from the BERA exposure assessment is because the likelihood that any species present in Portland Harbor comes in contact with or ingests such material is extremely unlikely.

Chemical contaminant data available for use in the BERA was collected during three rounds of sampling. Round 1 sampling, which focused on the collection of biota (tissue) samples, was conducted in 2002. Round 2 sampling began with multiple field efforts in 2004 and focused on the characterization of surface and subsurface sediment quality. Round 3 sampling occurred between 2006 and early 2008, and included collections of surface water, biota, sediment upstream and downstream of the Study Area, suspended sediments (in-river sediment traps), and stormwater samples. Round 3 sampling also filled data gaps related to site characterization, ecological and human health risks, upriver background contaminant concentrations, and the FS.

As a result of the systematic approach that was used to generate site data, the Portland Harbor

BERA is supported by an extensive, high quality database on the concentrations of numerous chemicals in multiple environmental media types (sediment, water, bird eggs and tissues from multiple fish and invertebrate species). In addition to this chemical dataset, a sizable number of sediment toxicity tests, which directly measured the effect of sediment contaminants on survival and growth of two benthic species was available. Finally, chemical concentrations of six chemicals in water that were toxic to Pacific lamprey ammocoetes (an immature life stage) were also identified during the BERA. The numbers of samples analyzed are summarized in Table ES-1.

Table ES-1. Numbers of samples chemically analyzed during the Portland Harbor BERA.

Location	Sediment	Sediment toxicity tests	Fish and invertebrate tissue	Bird eggs	Surface water	Transition zone water
Study Area (river mile 1.9 – 11.8)	1469	269	315	5	313	192
Downstream reach (river mile 0 – 1.9)	21	0	5	0	0	0
Multnomah Channel	7	0	0	0	0	0
Downtown reach (river mile 11.8 – 15.3)	17	2	6	0	0	0
Upstream (river mile 15.3 – 28.4)	22	22	18	5	0	0

Screening Level Ecological Risk Assessment (SLERA) Findings

The screening level ecological risk assessment (SLERA, Attachment 5 of this BERA, Steps 1 and 2 of the above 8-step process) identified numerous chemicals of potential ecological concern (COPC's) whose concentrations exceeded conservative screening level concentrations in sediment, water, tissues and ingested dietary doses. The SLERA concluded that the possibility for ecological risks from hazardous substances within Portland Harbor could not be discounted, and warranted further, more detailed investigation.

The SLERA evaluation was performed using the data collected during Round 1, Round 2 and a portion of the Round 3 sampling (Round 3 sampling was not complete at the time the SLERA was performed). In accordance with EPA ecological risk assessment policy and guidance, the more comprehensive baseline ecological risk evaluations described in this BERA were initiated. This BERA presents the findings of Steps 3 through 7 of the 8-step ecological risk assessment process.

BERA Problem Formulation

According to EPA (1997) guidance, a BERA problem formulation (Step 3 of the 8-step EPA ecological risk assessment process) generally consists of the following five tasks:

- Refinement of the preliminary list of chemicals of potential concern (COPCs) at the site;
- Further characterization of the potential ecological effects of COPCs at the site;

- Review and refinement of information on the fate and transport of COPCs, on potential exposure pathways, and on the receptors potentially at risk
- Selection of assessment endpoints (environmental values to be protected); and
- Development of a conceptual site model with testable hypotheses (or risk questions) that the BERA will address.

The products of the problem formulation are used to select measurement endpoints (what is actually measured at a site) and to develop the ecological risk assessment work plan (WP) and sampling and analysis plans (SAP's) for the site in Step 4 of EPA's ecological risk assessment process. In practice, Steps 3 and 4 of the 8-step EPA ecological risk assessment process are often, as was the case for Portland Harbor, performed concurrently.

Problem Formulation - Identification of Chemicals of Potential Ecological Concern (COPC's)

The refined screen, which resulted in the final chemicals of potential ecological concern (COPC) list evaluated in the BERA, is presented in Chapter 5 and Attachment 5 of this BERA. Table ES-2 presents the number of COPC's carried forward from the refined screen to the risk characterization step for each environmental medium evaluated.

Table ES-2 also lists the number of chemicals within each medium for which screening level or refined screen toxicity reference values could not be identified or derived. Unless baseline TRV's could be derived for the chemicals without screening level TRV's, ecological risks from the chemicals without baseline TRV's could not be quantified. Unquantified ecological risks from chemicals without baseline TRV's are likely the primary uncertainty of this BERA that underestimates ecological risks within Portland Harbor.

Table ES-2. Number of chemicals of potential concern (COPC's) evaluated in the BERA.

Medium or Diet	Chemicals of potential ecological concern (COPC's)	Chemicals without screening level TRV's
Sediment	67	106
Invertebrate tissue	18	23
Fish tissue	14	8
Fish dietary dose	9	11
Bird dietary dose	23	19
Mammal dietary dose	12	11
Bird egg tissue	5	0
Surface water	14	19
Transition zone water	58	14

The types or groups of chemicals identified as COPC's in the BERA are summarized in Table ES-3. Screening resulted in identification of a combined 104 COPCs for benthic invertebrates across four media types (sediment, invertebrate tissue, surface water, transition zone water). A combined 72 fish COPC's were identified when the results of the screening of all fish species analyzed were compiled, based on summing the COPC's across all media and for the dietary line of evidence. Twenty-three COPC's were identified for birds through two lines of evidence, and twelve COPC's for mammals were identified based on one line of evidence. Finally, 64 COPC's were identified for amphibians and aquatic plants through two lines of evidence. More detailed information regarding the final COPC list for the various receptors are found in BERA Table 5-1 (benthic invertebrates), Table 5-4 (fish), Table 5-7 (birds and mammals) and Table 5-10 (aquatic plants and amphibians).

Table ES-3. Chemicals of Potential Concern Forwarded to the BERA after Screening

Receptor group	Media evaluated	Number of COPCs	COPC chemicals
Benthic invertebrates, Bivalves, Decapods	Surface water, TZW, sediment, tissue	104	20 metals, 2 butyltins, 21 individual polycyclic aromatic hydrocarbons (PAH's) or PAH sums, 4 phthalates, 12 semi-volatile organic compounds (SVOC's), 6 phenols, 16 pesticide or pesticide sums, total polychlorinated biphenyls (PCB's), 2,3,7,8-TCDD (dioxin), 16 volatile organic chemicals (VOC's), 3 total petroleum hydrocarbon (TPH) fractions, cyanide, perchlorate
Fish	Surface water, TZW, sediment, diet, tissue	72	19 metals, 4 butyltins, 17 individual PAHs or PAH sums, bis(2-ethylhexyl)phthalate (BEHP), 3 SVOCs, total PCBs, 7 pesticide or pesticide sums, 18 VOCs, cyanide, perchlorate
Birds and mammals	Diet (birds and mammals), Bird eggs	23 (birds) 12 (mammals)	11 metals, 3 individual PAHs or PAH sums, 2 phthalates, total PCBs, dioxin TEQ, PCB TEQ, total TEQ, 3 pesticide or pesticide sums
Aquatic plants, amphibians	Surface water, TZW	64	15 metals, monobutyltin, 16 individual PAHs, BEHP, 3 SVOCs, total PCBs, 6 pesticide or pesticide sums, 18 VOCs, gasoline-range hydrocarbons, cyanide, perchlorate

Problem Formulation - Ecological Effects Characterization

Ecological effects characterization within the BERA problem formulation resulted in the final list of toxicity reference values (TRV's) for the various environmental media and samples evaluated. TRV's are chemical concentrations in media (e.g. sediment, water, tissue) or diets of ecological receptors which, if not exceeded, describe contaminant concentrations considered to pose no or only acceptable levels of ecological risk. Much of the TRV development work in this BERA was spent on two new TRV derivation methodologies which, to our knowledge, have never before been used in a baseline ecological risk assessment.

The floating percentile model (FPM, presented in BERA Attachment 6) was an effort to use site-specific sediment toxicity data to develop a model that could predict both toxicity at sediment sampling stations without measured toxicity data, and to define chemical concentrations in sediment that, if exceeded, would predict unacceptable levels of toxicity to benthic invertebrates. As complex sites such as Portland Harbor contain many contaminants, a model that can evaluate the toxicity of chemical mixtures would be of great benefit to the ecological risk assessment of not only Portland Harbor, but any sediment site where mixtures of contaminants may pose ecological risks. Because of these potential benefits, the FPM is also as of the date of this BERA proposed for use in dredging bioassessments throughout the Pacific Northwest, and by the State of Washington to derive freshwater sediment quality guidelines. Findings of the FPM were compared to a second predictive model of benthic toxicity, the logistic regression model (LRM), which has been used previously at other Superfund sites.

The tissue residue approach (TRA, presented in BERA Attachment 9) was used to derive chemical concentrations in fish and aquatic invertebrate tissues that, if exceeded, would define tissue contaminant concentrations posing potentially unacceptable ecological risks. While screening level ecological risk benchmarks for chemicals in aquatic life tissues have been available for some time, this BERA represents the first known effort to derive the numerous baseline ecological risk assessment tissue TRV's used in this BERA.

The remaining TRV's used in this BERA were taken from either existing compendia of environmental quality guidelines, or directly from the original scientific literature.

Problem Formulation - COPC Fate and Transport, Exposure Pathways, and Receptors at Risk

Contaminant sources and distribution within Portland Harbor, and their environmental fate and transport (Chapter 4, 5 and 6, respectively, of the remedial investigation report), as well as exposure pathways and identification of ecological receptors potentially at risk had largely been defined prior to development of the BERA problem formulation (EPA 2008j). Therefore, this stage of the problem formulation focused on identifying a series of surrogate species, termed target ecological receptors, for which ecological risks would be quantified in the BERA.

Given that Portland Harbor is inhabited by hundreds if not thousands of individual species, the majority of which are lower trophic level species such as algae and benthic invertebrates, the BERA evaluated risks to target ecological receptors, as it is not feasible to quantify risks to every species at the site. The primary selection criteria for target ecological receptors were: (1) that they represent the feeding guilds present at Portland Harbor; (2) that the target receptor utilized the same habitat as other similar species; (3) that the receptor be susceptible to contaminants; and (4) that the target receptor be ecologically, culturally or economically significant for the site. The term feeding guild refers to a group of species that share one or more functions within a system, such as similar feeding strategies or diets, thus resulting in a similar potential for contaminant exposure as other members of the guild.

Problem Formulation – Assessment Endpoint Selection

Perhaps the most important planning step of the entire BERA is the development of the assessment endpoints, risk questions, measurement endpoints, and lines of evidence to be assessed in a BERA. This is because combined, they establish the goals, breadth, and focus of the baseline ecological risk assessment. Brief definitions of the above four terms are as follows:

- ***Assessment endpoints*** - explicit expressions of environmental values to be protected
- ***Risk questions*** - proposed or suspected relationships between assessment endpoints and their predicted responses when exposed to contaminants
- ***Measurement endpoints*** - measurable ecological characteristics, either measures of exposure or measures of ecological effect that are related to the valued characteristics chosen as assessment endpoints
- ***Line of evidence*** - a set of data and associated analyses that can be used, either alone or in combination with other lines of evidence, to estimate ecological risks

For each assessment endpoint, risk questions and testable hypotheses are developed. Risk questions provide the basis for defining measurement endpoints that are evaluated with information collected during studies designed and performed as part of the remedial investigation of the site. Each measurement endpoint is evaluated with one or more lines of evidence.

An example of the relationship between assessment endpoints, risk questions, target ecological receptors, measurement endpoints and lines of evidence is given below for the aquatic plant assessment endpoint.

- ***Assessment endpoint*** – Survival, reproduction and growth of aquatic plants

- ***Risk questions / testable hypotheses*** - Are contaminant concentrations in Willamette River surface water or sediment transition zone water from Portland Harbor sediments greater than the toxicity thresholds for survival, growth, or reproduction of aquatic plants?

- ***Target ecological receptors*** – phytoplankton, periphyton, macrophytes (no specific plant species identified as target receptors for this particular assessment endpoint)

- ***Measurement endpoint*** - Water exposure contaminant concentrations compared to ambient water quality criteria (AWQC) or TRVs

- ***Line of evidence #1*** – Surface water chemical concentrations compared to literature-based TRV's or AWQC to protect sensitive life stages (e.g., germination, emergence, early life stage growth)

- ***Line of evidence #2*** – Transition zone water chemical concentrations compared to literature-based TRV's or AWQC to protect sensitive life stages (e.g., germination, emergence, early life stage growth)

The Portland Harbor BERA evaluated 13 assessment endpoints. Twelve of the 13 assessment endpoints took the form of "Survival, growth and reproduction of" a group of species that shared a habitat, taxonomic category or feeding guild.

The 12 assessment endpoints with the form "Survival, growth and reproduction of . . ." are:

1. Aquatic plants
2. Benthic macroinvertebrates
3. Bivalves
4. Decapods
5. Invertivorous fish
6. Omnivorous fish
7. Piscivorous fish
8. Amphibians
9. Piscivorous birds
10. Omnivorous birds
11. Invertivorous birds
12. Aquatic-dependent mammals

The 13th assessment endpoint was:

13. Survival and growth of detritivorous fish

The detritivorous fish assessment endpoint did not evaluate reproductive effects because the only target ecological receptor in this feeding guild, Pacific lamprey ammocoetes, is not the reproducing life stage of the lamprey.

The full list of 24 target ecological receptors, 31 measurement endpoints and 55 lines of evidence evaluated is presented in BERA Attachment 2, Table 1.

Problem Formulation – Conceptual Site Model Development

The last step of problem formulation, development of the conceptual site model (CSM) was also largely completed prior to commencement of work on the BERA problem formulation (EPA 2008j). A conceptual site model represents the known or hypothesized causal relationship between the source(s) of contamination and how (or if) the ecological receptors described in the BERA assessment endpoints are exposed to site contaminants. A simplified ecological CSM for Portland Harbor is presented in Figure ES-1.

Figure ES-1. Ecological conceptual site model for the Portland Harbor BERA

Graphics working on cartoon CSM

The routes of exposure are the means by which chemicals are transferred from a contaminated medium to ecological receptors. The most significant pathways by which ecological receptors may be exposed to Portland Harbor COPCs are:

- ***Aquatic plants*** - root uptake, direct contact with sediment, surface water and TZW
- ***Benthic invertebrates*** - direct contact with sediment, surface water and TZW, ingestion

of sediment and food

- ***Fish*** - direct contact with sediment, surface water and TZW, ingestion of sediment and food
- ***Birds and mammals*** - ingestion of soil, sediment, and food
- ***Amphibians*** - direct contact with surface water and TZW, ingestion of sediment and food

Study Design and Data Quality Objective Process

Tables 4-2 to 4-8 of the BERA describe the individual sampling events of sediment, water and biota during the BERA. All of the sampling and chemical analyses performed to obtain the date used in the BERA followed procedures defined in the ecological risk assessment work plan (Integral et al. 2004a) and the numerous sampling and analysis plans for various tasks.

The data quality objective (DQO) process used during the development of BERA sampling and analysis plans describes a series of planning steps that were employed to ensure that the type, quantity, and quality of environmental data collected for the BERA were adequate to support the intended uses of the data. The purposes of the DQO process were to:

- Clarify the study objective and define the most appropriate types of data to collect;
- Determine the most appropriate field conditions under which to collect the data; and
- Specify acceptable levels of decision errors used as the basis for establishing the quantity and quality of data needed to support risk assessment and risk management decisions.

Field Verification of Sampling Design

Step 5 of the 8-step ecological risk assessment process verifies that the selected assessment endpoints, testable hypotheses, exposure pathway model, measurement endpoints, and study design from Steps 3 and 4 are appropriate and implementable at the site. By verifying the study design, alterations can be made to the study design and/or implementation if necessary. These changes ensure that the ecological risk assessment meets its objectives.

Among the multiple changes made to various study plans during the three rounds of field sampling for the BERA, two are noteworthy. The original 2001 Administrative Order on Consent defined the Initial Study Area as river miles 3.5 to 9.2. As more information became available about the site, the need to expand the Study Area to answer questions identified not only during the BERA process, but other RI tasks resulted in expansion of the Study Area to its current definition of river miles 1.9 to 11.8.

The availability of radiotelemetry information on the movement of juvenile salmonids, smallmouth bass and northern pikeminnow (Friesen 2005) in the Study Area allowed the development of site specific home range estimates for these species. Site specific home range estimates for aquatic species are rare at Superfund sites, and the availability of such information for several target ecological receptors informed field sampling plans, and also allowed definition of species specific contaminant exposure concentrations for these species.

Site Investigation and Analysis of Exposure and Effects

Information collected during the site investigation (Step 6 of the 8-step EPA ecological risk assessment process) is used to characterize exposures and ecological effects. The site investigation includes all of the field sampling and surveys that are conducted as part of the ecological risk assessment. The site investigation and analysis of exposure and effects followed the ecological risk assessment work plan (Integral et al. 2004a) and the numerous sampling and analysis and field sampling plans developed and tested in Steps 4 and 5.

Ecological Exposure Assessment

To ensure conservatism (i.e. protectiveness) in the BERA, all COPCs were first evaluated on a sample-by-sample basis. Exposure of benthic invertebrates was assessed based on contaminant concentrations in individual samples of sediment, water, and TZW throughout the BERA, as these species have little or no ability to move within the Study Area.

Because a sample-by-sample exposure area is not ecologically relevant for the mobile receptors evaluated in the BERA (fish, birds and mammals), COPCs for mobile species were next evaluated at an exposure scale that is ecologically relevant for each specific receptor. The exposure area for mobile receptors was defined as the home range of each target ecological receptor. With the exception of the fish species for which site specific movement and home range information was available, home ranges were derived from the published ecological literature. For dietary risks to fish and wildlife, exposure estimates were also determined for a diet consisting of multiple prey species, using prey portions reported in the literature. Exposure concentrations are based both on contaminant concentrations quantified in the analytical laboratory (empirical concentrations), and, for some lines of evidence (LOE's), on predicted values (i.e., for the tissue residue LOE, the dietary LOE for shorebirds, and the bird egg LOE).

Ecological Effects Assessment

The effects assessment involves two general approaches. For most ecological receptors, the effects of COPCs were assessed by comparing contaminant concentrations in each environmental medium to chemical- and medium-specific TRVs or site-specific sediment quality values (SQV's). Consistent with the Problem Formulation, for all receptors and receptor groups evaluated at the community or population level, lowest-observed-adverse-effect level (LOAEL)

TRV's were used. No-observed-adverse-effect level (NOAEL) TRV's were used for receptors evaluated at the organism level (juvenile Chinook salmon, Pacific lamprey ammocoetes).

The second effects assessment approach uses sediment toxicity bioassays as a direct measure of the effects of sediment contaminant mixtures on the survival and biomass of benthic invertebrates in the laboratory. Two predictive models (floating percentile model, logistic regression model) were evaluated for the development of site-specific SQVs. The goals of both models were to predict benthic toxicity at locations without measured toxicity data, and to define site specific SQV's based on associations between measured sediment chemistry and measured sediment toxicity.

At Superfund sites, evidence of causality is key to the risk assessment process. Thus, it is important to evaluate the strength of the causal association between site related contaminants and their effects on the measurement and assessment endpoints (EPA 1997). An exposure-response correlation at a site by itself is not sufficient to demonstrate causality. Unless direct evidence of causality is available, one or more types of additional or supporting evidence, such as multiple lines of evidence leading to the same risk conclusion is needed. A commonly used set of criteria for evaluating causal associations between contaminants and ecological effects, and one identified for use in EPA (1997) ecological risk assessment guidance is that of Hill (1965)[3], which is summarized in Table ES-4.

Table ES-4. Hill's Criteria for Evaluating Causal Associations.

Criteria	Definition
Strength of Association	How large is the association between cause and effect
Consistency	Observation of association must be repeatable in different populations at different times
Specificity	A single cause produces a specific effect
Alternative Explanations	Consideration of multiple hypotheses before making conclusions on whether an association is causal or not
Temporality	Cause / exposure must precede the affect / outcome
Dose-Response Relationship	An increasing amount of exposure increases the risk
Biological Plausibility	The association agrees with currently accepted understanding of biological and pathological processes
Experimental Evidence	The condition can be altered, either prevented or accelerated, by an appropriate experimental process
Coherence	The association should be compatible with existing theory / knowledge, including knowledge of past cases and studies.

Risk Characterization

Risk characterization (Step 7 of the EPA (1997) 8-step ecological risk process) is the final phase of the BERA itself. During risk characterization, information from the exposure assessment and

[3] Hill, A.B. 1965. The environment and disease: Association or causation? Proceedings of the Royal Society of Medicine 58:285-300.

ecological effects assessment are combined into descriptions of the likelihood of unacceptable ecological risk to the assessment endpoints established during the problem formulation (Step 3 of the 8-step process). The risk characterization includes information on the chemicals posing potentially unacceptable risk, which ecological receptors are at risk, the media and exposure pathways in which chemicals posing potentially unacceptable risks are found, the magnitude of the risks, and the location(s) of risk within the Study Area.

In addition to the quantitative calculations performed to estimate risks, the risk characterization also discusses the level of agreement among multiple lines of evidence used to assess risks to the assessment endpoints, the relative strengths and weaknesses of each line of evidence, the ecological significance of identified risks, and the uncertainties associated with the risk assessment conclusions.

Direct evidence of causality, if available, provides the strongest line of evidence for a site posing potentially unacceptable ecological risks. Sediment toxicity tests with two species of benthic invertebrates, larvae of the aquatic insect *Chironomus dilutus* and juveniles of the amphipod *Hyalella azteca* were performed to evaluate adverse effects of Portland Harbor sediments on survival and biomass (a combined survival and growth endpoint) of these two species. These toxicity tests demonstrated that exposure of these animals to sediments from some locations within Portland Harbor resulted in increased mortality and/or reduced biomass of these two species within 10 to 28 days – a direct measure of sediment toxicity to benthic invertebrates within the Portland Harbor site.

Table ES-5. Sediment Toxicity Test Results.

Test	Level 0 (No toxicity)	Level 1 (Low toxicity)	Level 2 (Moderate toxicity)	Level 3 (Severe toxicity)
Chironomus survival	188 of 293	54 of 293	19 of 293	32 of 293
Chironomus biomass	201 of 293	37 of 293	12 of 293	43 of 293
Hyalella survival	253 of 293	19 of 293	2 of 293	19 of 293
Hyalella biomass	167 of 293	53 of 293	43 of 293	30 of 293
Percentage of site with risk	0	0	0	0

The moderate and severe levels of toxicity are not randomly scattered throughout the Study Area. Instead, most samples and locations eliciting multiple instances of moderate and severe toxicity tend to be clustered in the following areas (BERA Figures 6-2 through 6-5):

- River mile 3.3 to 3.5, east side of river
- Head of International Slip
- River mile 3.7 to 4.2, west side of river
- River mile 4.8 to 5.2, west side of river
- River mile 5.9 to 7.8, west side of river
- Willamette Cove

- River mile 6.9 to 7.5, east side of river
- Mouth of Swan Island Lagoon
- River mile 8.6 to 9.0, west side of river

Other individual samples and locations exhibit toxicity to *Chironomus* and *Hyalella*. However, the above areas are those within the Study Area where the greatest toxicity is found. Combined, the above areas can be estimated to cover between 4 – 8% of the total surface area of sediment within the Study Area[4]. Chemicals found at elevated concentrations in these areas are the most likely chemicals posing unacceptable ecological risks to benthic invertebrates.

Toxicity test results have several additional uses within the BERA. By using test organisms known to be sensitive to contaminants present within the Study Area, toxicity tests can suggest the overall susceptibility of the benthic community to site contaminants. Toxicity tests also help determine a site's post-remediation potential to support a viable ecological community (i.e. reduction of sediment contaminant concentrations to levels found at locations with no or low toxicity (Table ES-5) demonstrate the potential for benthic community recovery.

While toxicity tests directly demonstrate the adverse effects of sediment on benthic invertebrates, unfortunately they do not identify the chemical(s) responsible for the observed toxic effects. Exceedance of toxicity reference values by chemicals in environmental media or diets of ecological receptors is the primary method used in this BERA to identify which chemicals pose potentially unacceptable risks to ecological receptors.

Most risk characterizations in the BERA were made using hazard quotients (HQs). A hazard quotient is a comparison of an estimated exposure concentration in an environmental sample (EEC, also called an exposure point concentration or EPC in the BERA) to a toxicity reference value (TRV). Hazard quotients can also be comparisons of ingested dietary doses of contaminants to a dietary TRV, or comparisons of measured COPC concentrations in prey of target ecological receptors to acceptable tissue concentrations in prey species. The calculation of hazard quotients is presented in Equation 1:

Equation 1:

$$HQ = \frac{EEC_{medium} \text{ or } EPC_{medium}}{TRV_{medium}} \quad or \quad \frac{IR_{dietary}}{TRV_{dietary}} \quad or \quad \frac{C_i}{ATC_{prey}}$$

Where:

HQ = hazard quotient (dimensionless)

[4] Estimates of the proportion of the Study Area eliciting moderate or severe toxicity to benthic invertebrates are made using geographic information system (GIS) models. Different GIS models make different extrapolations of contaminated areas between sample locations of known levels of contamination or toxicity, thus accounting for the range in the estimates of the percentage of the Study Area that elicits moderate or severe toxicity.

EEC_{medium} = estimated exposure concentration of a chemical in a specific medium (e.g. water, sediment, tissue), units specific to medium (e.g. µg/L for water, mg/kg or µg/kg for sediment)

EPC_{medium} = exposure point concentration of a chemical in a specific medium (e.g. water, sediment, tissue), units specific to medium

TRV_{medium} = toxicity reference value for a specific COPC in a specific medium (e.g. water, sediment, tissue), or for a specific assessment endpoint or group of assessment endpoints (e.g. bivalves, fish), units specific to medium, but the same as EEC_{medium} or EPC_{medium}

$IR_{dietary}$ = ingestion rate (or ingested daily dose) of a COPC, normalized to the body weight of the receptor of interest, mg/kg body weight/day)

$TRV_{dietary}$ = toxicity reference value for a specific COPC in the diet of a receptor of interest, normalized to the body weight of the receptor, mg/kg body weight/day)

C_i = COPC concentration in tissues of the i^{th} prey species, mg/kg

ATC_{prey} = acceptable tissue concentration in prey species, mg/kg

COPCs for which the HQ ≥ 1.0 were identified as chemicals posing potentially unacceptable risk at the conclusion of the BERA. The potential for unacceptable risk becomes increasingly large as the hazard quotient value increases, although the increase is not necessarily linear (i.e. a sample with a HQ = 2.0 does not necessarily have twice the risk of a sample with a HQ = 1.0).

The complete list of chemicals posing potentially unacceptable ecological risks to the BERA assessment endpoints, the exposure pathways by which chemicals pose risks, and sections of the BERA where additional details can be found regarding the magnitude of risks, risks to specific target ecological receptor species, and locations within the Study Area where risks are found, are presented in Table ES-6.

Table ES-6. Chemicals Posing Potentially Unacceptable Ecological Risks within the Portland Harbor Study Area.

Assessment Endpoint	Exposure Pathway	Chemicals with HQ ≥ 1.0	Additional Details
Aquatic plants, Amphibians	Surface water	4,4'-DDT, benzo(a)anthracene, benzo(a)pyrene, bis(2-ethylhexyl)phthalate, ethylbenzene, monobutyltin, naphthalene, total DDx, total PCB, trichloroethene, zinc	Section 9-1 (amphibians), Table 9-??. Section 10-1 (aquatic plants), Table 10-??.
	Transition zone water	1,1-dichloroethene, 1,2,4-trimethylbenzene, 1,2-dichlorobenzene, 1,3,5-trimethylbenzene, 1,4-dichlorobenzene, 2,4-DDD, 2,4-DDT, 2-methylnaphthalene, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, acenaphthene, anthracene, barium, benzene, benzo(a)anthracene, benzo(a)pyrene,	Section 9-2 (amphibians), Table 9-??. Section 10-1 (aquatic plants), Table 10-??.

		benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, beryllium, cadmium, carbon disulfide, chlorobenzene, chloroethane, chloroform, chrysene, cis-1,2-dichloroethene, cobalt, copper, cyanide, dibenzo(a,h)anthracene, dibenzofuran, ethylbenzene, fluoranthene, fluorene, gasoline fraction (aliphatic) $C_4 – C_6$, gasoline fraction (aliphatic) $C_6 – C_8$, gasoline fraction (aliphatic) $C_{10} – C_{12}$, gasoline fraction (aromatic) $C_8 – C_{10}$, indeno(1,2,3-cd)pyrene, iron, isopropylbenzene, lead, m,p-xylene, magnesium, manganese, naphthalene, nickel, o-xylene, perchlorate, phenanthrene, potassium, pyrene, sodium, toluene, total DDx, total xylenes, trichloroethene, vanadium, zinc	
Benthic invertebrates, Bivalves, Decapods	Sediment	2,4'-DDD, 2-methylnaphthalene, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, 4-methylphenol, acenaphthene, acenaphthylene, ammonia, anthracene, Aroclor 1254, arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, benzyl alcohol, cadmium, carbazole, chlordane (cis and trans),chromium, chrysene, cis-chlordane, copper, dibenzo(a,h)anthracene, dibenzofuran, dibutyl phthalate, dieldrin, diesel range organics, endrin, endrin ketone, fluoranthene, fluorene, heptachlor epoxide, indeno(1,2,3-cd)pyrene, lead, lindane (γ-HCH), mercury, naphthalene, nickel, phenanthrene, phenol, pyrene, silver, sulfide, sum DDD, sum DDE, sum DDT, total chlordane, total DDx, total endosulfan, total HPAH, total LPAH, total PAH, total PCB, tributyltin, zinc, β-HCH, δ-HCH	Sections 6-2 and 6-3. Tables 6-12, 6-13, 6-16, 6-20, 6-44, 6-??. Maps 6-7 through 6-21.
	Surface water	4,4'-DDT, benzo(a)anthracene, benzo(a)pyrene, bis(2-ethylhexyl)phthalate, ethylbenzene, monobutyltin, naphthalene, total DDx, total PCB, trichloroethene, zinc	Section 6-5. Tables 6-33, 6-34, 6-36.
	Transition zone water	1,1-dichloroethene, 1,2,4-trimethylbenzene, 1,2-dichlorobenzene, 1,3,5-trimethylbenzene, 1,4-dichlorobenzene, 2,4-DDD, 2,4-DDT, 2-methylnaphthalene, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, acenaphthene, anthracene, barium, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, beryllium, cadmium, carbon disulfide, chlorobenzene, chloroethane, chloroform, chrysene, cis-1,2-dichloroethene, cobalt, copper, cyanide, dibenzo(a,h)anthracene, dibenzofuran, ethylbenzene, fluoranthene, fluorene, gasoline fraction (aliphatic) $C_4 – C_6$, gasoline fraction (aliphatic) $C_6 – C_8$, gasoline fraction (aliphatic) $C_{10} – C_{12}$, gasoline fraction (aromatic) $C_8 – C_{10}$, indeno(1,2,3-cd)pyrene, iron, isopropylbenzene, lead, m,p-xylene, magnesium, manganese, naphthalene, nickel, o-xylene, perchlorate, phenanthrene, potassium, pyrene, sodium, toluene, total DDx, total xylenes, trichloroethene, vanadium, zinc	Section 6-6. Table 6-41.
	Tissue	4,4'-DDD, arsenic, bis(2-ethylhexyl)phthalate, copper, total DDx, total PCB, tributyltin, zinc	Section 6-4. Tables 6-25, 6-29.
Fish	Surface water	4,4'-DDT, benzo(a)anthracene, benzo(a)pyrene, bis(2-ethylhexyl)phthalate, ethylbenzene, monobutyltin, naphthalene, total DDx, total PCB, trichloroethene, zinc	Section 7-3. Tables 7-36 through 7-39.
	Transition zone water	1,1-dichloroethene, 1,2,4-trimethylbenzene, 1,2-	Section 7-4.

		dichlorobenzene, 1,3,5-trimethylbenzene, 1,4-dichlorobenzene, 2,4-DDD, 2,4-DDT, 2-methylnaphthalene, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, acenaphthene, anthracene, barium, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, beryllium, cadmium, carbon disulfide, chlorobenzene, chloroethane, chloroform, chrysene, cis-1,2-dichloroethene, cobalt, copper, cyanide, dibenzo(a,h)anthracene, dibenzofuran, ethylbenzene, fluoranthene, fluorene, gasoline fraction (aliphatic) $C_4 – C_6$, gasoline fraction (aliphatic) $C_6 – C_8$, gasoline fraction (aliphatic) $C_{10} – C_{12}$, gasoline fraction (aromatic) $C_8 – C_{10}$, indeno(1,2,3-cd)pyrene, iron, isopropylbenzene, lead, m,p-xylene, magnesium, manganese, naphthalene, nickel, o-xylene, perchlorate, phenanthrene, potassium, pyrene, sodium, toluene, total DDx, total xylenes, trichloroethene, vanadium, zinc	Tables 7-42, 7-44.
	Fish tissue	Antimony, bis(2-ethylhexyl)phthalate, copper, lead, total DDx, total PCB	Section 7-1. Tables 7-7 through 7-10.
	Diet	Cadmium, copper	Section 7-2. Tables 7-23 through 7-27.
Birds	Diet	Aldrin, benzo(a)pyrene, copper, dibutyl phthalate, lead, mercury, sum DDE, total DDx, , total dioxin/furan TEQ, total PCB, total PCB TEQ, total TEQ	Section 8-1. Table 8-??.
	Bird egg tissue	4,4'-DDE, total dioxin/furan TEQ, total PCB, total PCB TEQ, total TEQ	Section 8-2 Table 8-??.
Mammals	Diet	Aluminum, lead, total dioxin/furan TEQ, total PCB, total PCB TEQ, total TEQ	Section 8-1. Table 8-??.

Risk characterization would not be complete without mention of the lines of evidence where no ecological risks were identified. Table ES-7 lists the lines of evidence for several assessment endpoints where no ecological risks were identified.

Table ES-7. BERA Lines of Evidence where No Unacceptable Ecological Risks Were Identified.

Assessment Endpoint	Measurement Endpoint	Line of Evidence
Survival, growth, reproduction of benthic invertebrates	Benthic invertebrate tissue data compared to tissue TRV's	Field-collected epibenthic macroinvertebrate tissue concentration (from Hester-Dendy samplers) relative to tissue TRVs
Survival, growth, reproduction of bivalves	Sediment toxicity testing to empirically assess adverse effects	*Corbicula fluminea* survival in 28 day bioaccumulation test
Survival, growth, reproduction of invertivorous fish	Ingested dietary dose of contaminants compared to dietary TRVs	Dietary dose compared to dietary TRVs to also include stomach content data or other approaches refined specifically for PAHs (juvenile Chinook salmon only)
Survival, growth, reproduction of omnivorous fish	Fish tissue data (modeled or field collected) compared to tissue based TRV's	Tissue-based TRV approach for dioxin-like contaminants using literature values and incorporating toxic equivalents (TEQs) based on the World Health Organization toxic equivalent factors (TEFs). Risk from

	other compounds assessed in uncertainty analysis (chemical specific, carp only).

Ecological Significance of Identified Risks

In ecological risk assessment, the ecological significance of the identified risks is often evaluated by answering the question "So what?" That is, if the risks exist as estimated, will they make a difference or be observed in addition to other factors operating in the environment, such as habitat alteration?

With the exception of species protected by law or regulation (e.g. threatened and endangered species) where individual organisms are protected, EPA guidance and policy states that ecological risk assessments should generally focus on protection of local populations and communities of biota (e.g. the Study Area population of smallmouth bass, not the global population of smallmouth bass, which exist on four continents).

Oregon's ecological risk assessment guidance (ODEQ 1998) also focuses on risks to local populations. ODEQ (1998) defines a local population for a stream or river as follows: "For aquatic species in moving water such as streams and rivers (lotic habitats), the local population comprises all individuals of the endpoint species within the stream segment within the contaminated area."

Contaminant concentrations which, if not exceeded are protective of local populations and communities were largely estimated in this BERA by extrapolating from effects on individual organisms or groups of organisms using a lines of evidence approach. HQs ≥ 1 are considered to indicate potential risk to ecological receptors, for example reduced or impaired reproduction or recruitment of new individuals. The HQs provide insight into the potential for adverse effects upon organisms in the local population resulting from chemical exposure. If an HQ indicates risks are present for an average organism of a species, then risks may be present for the local population.

Ecological significance can be defined as the importance of an adverse effect to population, community or ecosystem responses. Several factors contribute to ecological significance, including the nature and magnitude of effects, the spatial and temporal extent of effects, and the recovery potential under partial or complete removal of contaminants. However, as there are no specific directions in EPA ecological risk assessment guidance describing how to quantify ecological significance, the guidance (EPA 1997) calls for risk assessors to use professional judgment when describing the ecological significance of identified risks. Different risk assessors may have legitimately different opinions on the ecological significance of identified risks, which is one of the primary reasons risk management decisions at Superfund sites are the responsibility of risk managers, not risk assessors. This is because risk managers are required to consider multiple factors such as protection of human health, effectiveness and permanence of the risk reduction, ability to implement management decisions, costs, and state and community acceptance when making their risk management decisions, in addition to the information in this BERA.

Common sense dictates that ecological risks from, for example 1,1-dichloroethene, which was detected at concentrations resulting in an HQ ≥ 1 in only one medium (transition zone water), in only two of 136 TZW samples, and with a maximum HQ = 1.6, are not as ecologically significant as risks from PAH's. PAH's pose potentially unacceptable risks to multiple ecological receptors via multiple exposure pathways throughout a significant proportion of the Study Area, including some of the locations with the greatest benthic toxicity as measured by sediment toxicity tests. Individual PAH compounds have HQ's as high as in 1500 in sediment, 50 in surface water and 2700 in TZW.

Starting with the above factors that contribute to ecological significance (nature and magnitude of effects, spatial and temporal extent of effects, recovery potential after remediation), EPA has identified the following criteria that can be used to make judgments regarding the chemicals posing potentially unacceptable risks with the greatest ecological significance:

1. Chemicals with high hazard quotients in one or more environmental media
2. Chemicals posing risks over extensive spatial areas
3. Chemicals whose spatial extent of risk encompasses many other chemicals that pose risk at only one or a few locations in the Study Area
4. Chemicals posing risks to multiple ecological receptors
5. Chemicals where multiple lines of evidence indicate risks
6. Chemicals whose frequency of or distribution within the Study Area of HQ ≥ 1.0 is high
7. Chemicals with unusual (compared to other site chemicals) modes of toxic action; or
8. Chemicals with high bioaccumulative potential, or known to biomagnify in food webs

Using the above criteria as a guide to identifying the chemicals posing potentially unacceptable risk with the greatest ecological significance, the following chemicals were identified:

Table ES-8. Chemicals Most Likely to Pose Significant Unacceptable Ecological Risks.

Chemical	
Total PAH's	Total TEQ
Total PCB's	PCB TEQ
Total DDx	Dioxin / furan TEQ
Total Chlordanes	Mercury
Sum DDD's	Cadmium
Sum DDE's	Bis(2-ethylhexyl)phthalate (BEHP)
Sum DDT's	Dieldrin
Lead	Cyanide
Copper	Ethylbenzene
Zinc	Perchlorate
Lindane (γ-HCH)	$C_{10} – C_{12}$ total petroleum hydrocarbons (TPH)
Tributyltin	Manganese

Benzo(a)pyrene	Vanadium

Ecological Risk Assessment Uncertainties

By design, risk assessments are conservative in the face of uncertainty. In this context, conservative means efforts were made to minimize the chances of underestimating exposure or risk. The uncertainty analysis portions of this BERA are intended to illustrate the degree of confidence in the BERA conclusions. Uncertainty analysis can help the risk manager focus on those aspects of ecological risk that can be reduced during site remediation with the greatest certainty that the selected remedy will result in a benefit to and protection of the environment.

Uncertainty in a BERA has four components: variation (e.g. a fish is exposed to a range of chemical concentrations in water, not to a constant concentration of a chemical); model uncertainty (e.g. use of a single species or several target ecological receptors within a feeding guild to represent all species within that guild introduces uncertainty because of the considerable amount of interspecies variability in sensitivity to a chemical); decision rule uncertainty (e.g. use of standard EPA default values such as assuming chemicals are 100% bioavailable, because such defaults are used as single point values throughout the BERA, despite having both variation and model uncertainty associated with them); and true unknowns (e.g. the toxicity of titanium in water to smallmouth bass has never been studied, and is unknown).

Consistent with the methods of EPA's Problem Formulation (EPA 2008j), receptor-contaminant pairs posing potentially unacceptable risk were identified using conservative methods and assumptions. Examples of conservatism include assumptions that environmental contaminant concentrations are 100% bioavailable, and assumptions resulting in low baseline toxicity reference values (TRVs) that, in the case of nutritionally essential metals such as copper, had to be adjusted upward because they were below nutritional requirements for some, but not all, fish species.

Not all uncertainties create a conservative bias. Some can lead to underestimation of risk, for example unavailability of exposure or effects data, thresholds that do not account for untested sensitive species, synergistic interactions among the multiple chemicals present at the site, and metabolic processes that increase the toxicity of accumulated chemicals.

Primary Conclusions of the BERA

Combining the findings of the BERA as summarized in Tables ES-5, ES-6, ES-7 and ES-8, and as described in more detail in the BERA itself and its attachments, including the evaluations of ecological significance and uncertainty, the following primary conclusions can be made.

- In total, 102 contaminants (as individual chemicals, sums, or totals) with HQ ≥ 1 pose potentially unacceptable ecological risk.

- Differences in the specific TRV's used in different lines of evidence for Total PCB (e.g., Total PCB vs. specific Aroclor mixtures), Total DDx (e.g. Total DDT's, Total DDD's, Total DDE's, six individual chemicals), and Total PAHs (many individual chemicals such as naphthalene, as well as several groupings by molecular weight), all of which describe individual chemicals or a group of multiple, but related individual chemical compounds, can result in different counts of the number of chemicals posing potentially unacceptable risks. The list of chemicals posing potentially unacceptable risks can be condensed if all PCB, DDx and PAH compounds or groups are condensed into three comprehensive groups: Total PCB's, Total DDx and Total PAH's. Doing so reduces the number of contaminants with HQ ≥ 1.0 posing potentially unacceptable risks to 74.

- Risks to benthic invertebrates as identified by sediment toxicity tests are clustered in the following sections of the Study Area: River mile 3.3 to 3.5, east side of river; Head of International Slip; River mile 3.7 to 4.2, west side of river; River mile 4.8 to 5.2, west side of river; River mile 5.9 to 7.8, west side of river; Willamette Cove; River mile 6.9 to 7.5, east side of river; Mouth of Swan Island Lagoon; River mile 8.6 to 9.0, west side of river

- Sediment and transition zone water samples with the highest hazard quotients for many chemicals also tend to be clustered in the areas with the greatest benthic invertebrate toxicity

- The COPCs in sediment that are most commonly spatially associated with locations of potentially unacceptable risk to the benthic community or populations are PAHs, PCBs, and DDx compounds.

- Not all chemicals posing potentially unacceptable risks have equal ecological significance. Table ES-8 describes the judgment of ecological risk assessors regarding the chemicals posing risks with the greatest ecological significance.

- The list of ecologically significant chemicals in Table ES-8 is not intended to suggest that other contaminants in the Study Area do not also present potentially unacceptable risk.

- The chemicals identified as posing risks in the largest numbers of lines of evidence are (in decreasing frequency of occurrence) total PCB, copper, tributyltin, total DDx, zinc, lead, total toxic equivalents (total TEQ), PCB TEQ, benzo(a)pyrene, mercury, cadmium, 4,4'-DDE, dioxin/furan TEQ, bis(2-ethylhexyl)phthalate, naphthalene, and benzo(a)anthracene. The remaining 86 chemicals of concern pose risks to three or fewer lines of evidence.

- Of the three groups of chemicals (total PAH's, total PCB's, total DDx) with the greatest areal extent of $HQ \geq 1.0$ in the Study Area, PAH risks are largely limited to benthic invertebrates and other sediment-associated receptors. PCB's and DDx tend to pose their largest ecological risks to birds, mammals, and either higher trophic level fish such as smallmouth bass, or fish species associated with sediment or which feed on benthic invertebrates (e.g. largescale sucker, sculpins).

- The combined toxicity of dioxins/furans and dioxin-like PCBs, expressed as total toxic equivalents (TEQ), poses the potential risk of reduced reproductive success in mink, river otter, spotted sandpiper, bald eagle and osprey. The PCB TEQ fraction of the total TEQ is responsible for the majority of total TEQ exposure, but the total dioxin/furan TEQ fraction also exceeds its TRV in some locations of the Study Area.

Risk Management Recommendations

Under EPA guidance, risk management (Step 8 of EPA's 8-step ecological risk assessment process) is a distinctly different process from risk assessment. Risk management decisions at Superfund sites are made by EPA risk managers. These risk managers are the EPA remedial project managers for the site. Risk management decisions **are not** made by the risk assessors who prepared the BERA.

As risk managers normally ask risk assessors for their recommendations, advice and professional judgment before making their risk management decisions, EPA asked the LWG to have their ecological risk assessors gather and provide any risk management recommendations they might have in a separate section of the BERA. As a result of this request, Section 12 of this BERA identifies the COCs, receptors, and AOCs that the LWG considers necessary and sufficient to develop and evaluate remedial alternatives that are protective of ecological resources. The FS will also evaluate whether remedial alternatives for these COCs, receptors, and AOCs address the full list of contaminants posing potentially unacceptable risk. EPA's ecological risk management recommendations are presented in a standalone technical memorandum that is not part of this BERA.